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GENERAL REVIEWS AND SUMMARIES

THE FUNCTIONS OF THE CEREBRUM

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General.—In every science it is advisable from time to time to consider how much of our apparent knowledge is conjecture or assumption and how much is inherent in the results of our observations. It is obviously necessary to do this frequently in connection with the subject of cerebral localization. Using the title "new phrenology" to designate the ill-founded conclusions of the histological localizations, Franz (23) criticized certain recent views, and this has led to a number of counter-criticisms, based upon misreadings of the paper or upon preconceptions. Pike (49), for example, has apparently disregarded the meaning in which the term "new phrenology" was used, and assumes that an attack has been made upon the possibility of cerebral localization. Bouché (8) also has been led to defend the old cult, although he approaches the standpoint he attacks, for he is forced to admit that at the present time we are ignorant of the histological appearances which characterize function. In its proper form, the general doctrine is acceptable, but in the way it is exposed by some recent authors the doctrine is not only open to, but invites critical attack. To question what and how far histological studies may contribute to our knowledge of the localization of mental function is not in itself hostile to localization; it is simply an attempt to limit some of the vagaries of reasoning which are rampant when the mental functions of the cerebrum are being considered. In the reasoning regarding the relation of the brain and mental processes it is not uncommon to find middle terms omitted, in a fashion like the following: Destruction of the occipital

cortex is followed by blindness; therefore, the cells in the calcarine type of cortex normally contain visual memories and ideas. Regarding this matter van Valkenburg (60), who has critically considered the facts, has written: "One cannot say more than that the said region (occipital cortex) has something to do with visual impressions . . . the simplest function possible, the feeling of a touch or the hearing of a sound, is for the present not capable of localization in an anatomical sense."

The diaschisis hypothesis (see PSYCHOLOGICAL BULLETIN, 1911, 8, 112–113), which explains many of the symptoms in cerebral lesions not accounted for on the ground of separate centers, is again set forth by von Monakow (46) in a well-written article.

Attempts have been made to answer the question: By what parts of the nervous system may an animal form associations? The answers have usually been, "the cerebrum." This is the answer given by Burnett (10) who deprived frogs of their cerebral hemispheres, and later tried to get the animals to acquire a simple habit. Although, the author concludes, the frogs died too soon for the question to be answered definitely, the animals exhibited no different reaction after a series of tests sufficient in number for a normal animal to form the association.

Although the extirpation of small areas of the cerebral cortex in mammals is not without certain technical difficulties, the total extirpation of one or both hemispheres with retention of life by the animal is attended with difficulty proportionately greater than the relative amounts of substance taken away. Karplus and Kreidl (33, 34) have, however, been able to extirpate one or both hemispheres of monkeys. When one hemisphere was taken away the animal exhibited motor disturbances, more marked in the opposite fore limbs, and sensory alterations. When both hemispheres were taken away (in two animals which lived respectively eight and twelve days) the animal became paretic, slept (?) most of the time, but when awake, or with eyes open, the latter were moved in all directions and reacted to stimuli. The movements of the head and eyes were not greatly impaired by the removal of the cerebrum, but the greatest effect was a lack of spontaneity. Unfortunately, the brief accounts of the work do not include descriptions of the brains after death, and these will be awaited with interest.

Movement.—The relation of the parts of the cerebrum to the production of movement has been the most studied problem in cerebral localization, but there yet remains much to be done before

there is a complete understanding of it. The cortex anterior to the central fissure is now generally believed to be motor, and that posterior to that fissure sensory, but Bianchi (7) has described movement disorders following destruction of the posterior region. It is true that these effects are only transitory, but they are sufficiently evident to cause some doubt regarding the purely sensory function of the postcentral cortex. In fact, Rothmann (54), from experiments on monkeys, concludes that the cortex surrounding the central fissure is sensory-motor, and in this he returns to the view more generally held fifteen years ago. He believes that the two parts, anterior and posterior to the Rolandic fissure, have the same general function, but that there has been some differentiation in that the posterior part is more sensory than motor.

Franz (19) and others have described cases in which the principal symptoms from lesion in the postcentral areas were motor, *e. g.*, epileptic seizures, and it is also known that disease of a part of the brain other than that surrounding the central fissure may cause epileptoid phenomena. This condition has been reported for the temporal lobes by Astwazaturow (2), who in an examination of the literature also found half of the cases of temporal lobe tumor associated with an epilepsy.

By means of an ingenious method, that of passing very cold solutions over parts of the motor area so that the temperature of the cortex became much lower than normal (as low as 13.3° C.), Trendelenburg (59) produced a temporary condition similar to that produced by the extirpation of the cortex. The phenomenon of paralysis was particularly noticeable, and this corresponded with the results of stimulation and extirpation by other investigators. Mott, Schuster and Sherrington (45) have continued to make stimulation tests and report the results of the examination of the brain of the gibbon. The most noteworthy results are those in relation to the eye movements following stimulation of the occipital cortex. They report that the eye movements result from the stimulation of the cortex surrounding the calcarine fissure, but not from the stimulation of other parts of the occipital pole.

Grauer (26) has described some of the motor phenomena, excluding paralysis, occurring after cortical lesions, with especial reference to athetosis. Jones (32) has attempted to differentiate cortical zones for the tongue movements and has suggested an explanation for the variations in the deviation of the tongue in hemiplegia. An interesting study has been reported by Lewy (36) who studied in monkeys

the histological characters of muscles in the paralytic and spastic conditions following the extirpation of the motor cortex. At intervals after the removal of parts of the cortex he took pieces of the muscles and found that the striations persisted and that, notwithstanding the paralysis and spasticity, there was no evidence of muscular degeneration. These facts are of special interest in connection with the question of nutritive control by the cortical cells.

In addition to the cortex, the lenticular and caudate nuclei are known to be concerned in the production of, or to have a controlling effect upon, movements. Principally because of the contentions of Marie, many studies have been made of the conditions accompanying lesions of the lenticular nucleus and the associated structures. The functions of the lenticular nucleus, as shown by the symptoms in the patients observed by Mingazzini (42) are not simple. He observed that lesions of this nucleus were accompanied by slight facial paresis and a paresis of the extremities on the opposite side, and at times atrophy of the extremities and slight disturbances of the skin sensations. He also observed that if the posterior part of the nucleus be destroyed dysarthria results, and if the lesion includes part of the putamen, excepting the outer third, paresthesias result. Vogt (61) has also found motor defects accompanying lesions of the corpus striatum, but concludes that this body does not produce, but controls, movement. Although the optic thalamus is now admitted to be a subsidiary sensory center, motor effects, especially choreiform and athetoid, are accompaniments of its destruction, but Holmes and Head (30) did not find these in the patient under their observation, and they found little or no paralysis.

Vicarious Function of Cerebral Areas, as Shown by Motor Control after Nerve Anastomosis.—It is well known that if two motor nerves be cross-sutured there may eventually result a return of function in both parts. Thus, in infantile paralysis it is possible to obtain a return of function in a paralyzed part by taking a part or all of a nerve and uniting it with the nerve which normally effects movement in the paralyzed part. Feiss (17) reports a case which well illustrates this fact. This procedure has been made much use of during the past few years, and it has been shown that the return of function results even when the nerves cross-sutured innervate different anatomical segments. Several years ago, Kennedy crossed the nerves for the flexor and extensor movements of the dog's leg and noted that after a time the animal was able to move the leg quite properly. He also found that when the brain in the motor region

was stimulated, the stimulation of the normal flexion center was accompanied by an extension, and vice versa, indicating that new brain connections had been made. These results are somewhat open to question on account of the proximity of these two cortical centers, but the probability of new connections being formed has been amply demonstrated by the work of Osborne and Kilvington (48), who crossed part of the central portion of the left brachial plexus to the peripheral portion on the right, tying off the central part on the right side to prevent regeneration. They found that after three hundred days there was a return of function in the right leg, and upon stimulation of the cortical center on the right, which normally results in movement on the left, they found movements of both fore limbs, indicating that the control from the right side of the cerebrum was made for both limbs. This demonstrates that "an interchange of function can readily occur in the motor centers of the cerebral cortex." The further series of experiments by Kennedy (35) are also of interest, for he found that it was possible to obtain return of function by connecting the spinal accessory with the distal part of the facial or the hypoglossal with the facial. The first movements in the facial area followed the operations in fifty-eight and thirty-two days respectively, and complete voluntary control of the closure of the eye, normally controlled by the facial nerve and center, occurred in about one hundred days. Results of this nature indicate how little we now know regarding what has been believed to be a simple relation of cerebral action and movement.

Skin and Movement Sensations.—A few years ago one of the most unsatisfactory chapters in cerebral localization was that dealing with the skin and muscle sensations. There have now been published, however, numerous reports of examinations of patients with disturbances of these types of sensation, which are leading to a better understanding of the functions of the cortical areas and the underlying gray masses. The most extensive and important recent contribution to this subject is that of Head and Holmes (28), who have dealt with the course of the impulses as well as with their cortical and subcortical centers. Of the ganglionic gray masses the optic thalamus, and of the cortex the postcentral area, are the most important parts for the sensations. Destruction of the thalamus produces marked disturbances of these sensations, more particularly of that of posture and that of movement; touch is frequently diminished, temperature stimuli are not correctly appreciated, but the vibration sensations and the recognition of degrees of roughness are not greatly affected.

Lesions of the cerebral cortex produce heightened thresholds of different nature; at times, *e. g.*, in temperature tests and tests of vibration sensations, the sensations are only less plain than from a corresponding normal part; the appreciation of weight, of size and of form and the sense of posture and of movement are most frequently affected, but painful stimuli are equally as painful as on a corresponding normal area. It has also been pointed out by Muskens (47) (*a*) that the defects of sensibility from cortical lesions concern the peripheral more than the proximal portions of the limbs; (*b*) that touch, the sense of localization, stereognosis and the muscle sense are more strongly represented in the cortex than the sensations of pain and temperature; but (*c*) that the sensory cortical areas for the limbs are greater than the corresponding motor areas. Bianchi (7) has noted certain variations. In five cases of lesions of the parietal region he has observed disturbances of movement, which are transitory, with a more or less complete hemianesthesia and astereognosis. Holmes and Head (30) also describe a case in which the ventral and lateral parts of the optic thalamus were softened and the patient exhibited a complete loss of tactile and posture sensations on the opposite side of the body with loss of the appreciation of temperature sensations. The case of Beyerman (6) with lesion in the outer part of the left lenticular nucleus, in the right thalamus, and in part of the parieto-occipital cortex, showed left anesthesia, no temperature appreciation, a hypersensitivity to pain and disturbance of the muscle sense. On the other hand, a cyst in the postcentral region of the cortex in the case described by Franz (19) resulted, on the sensory side, in only slight hypoesthesia in the shoulder. Edwards (16) has also described a case in which a tumor near the supramarginal convolutions was associated with impairment of sensation in both arms and abolition of muscle sense and astereognosis. After operation, the patient improved, although there persisted some impairment of muscle sense and of stereognosis and of touch. Hemianesthesia was found by Spiller and Camp (57) accompanying lesions of the posterior part of the internal capsule and the lenticular nucleus, and Mingazzini (42) also found hypoesthesia in disturbances of the lenticular nucleus, and, if part of the putamen be included, paresthesias.

The general conclusions of Head and Holmes (28) regarding the relation of the thalamus and the cortex are summed up as follows: the thalamus "contains the termination of all secondary paths . . . (in it) the sensory impulses are grouped afresh and redistributed in two directions . . . to the cerebral cortex . . . and to the gray

matter of the thalamus itself." The gray matter of the thalamus "forms the center for certain fundamental forms of sensation." The sensory cortex is "concerned more particularly with the discrimination and with the relation between two sensations, or between a sensation and its representation." Moreover, "all stimuli which appeal to the thalamic center have a high threshold. They must reach a high intensity before they can enter consciousness, but once they have risen above the threshold they tend to produce a change of excessive amount and duration and this it is the business of the cortical mechanism to check."

Hearing.—Although normally the temporal lobes are comparatively smooth, Auerbach (3) has found the first temporal convolutions markedly tortuous in a musician, and this change he associated with musical ability. A case of deafness, the brain of which is descrbed by Berger (5), showed lesions in the first and second temporal convolutions on both sides, but Berger associates the deafness with the lesions in the first temporals alone. A somewhat similar condition was observed by Gans (25) in a deaf-dumb-blind individual, the temporal cortex exhibiting a decrease of cells in the granular and multiform layers. Associated with the cortical deficiencies there were changes in the posterior quadrigeminal and the internal geniculate bodies. The disturbances of hearing reported by Holmes and Head (30), probably resulted from the affection of the internal geniculate body or the interruption of the corticopetal fibers from the latter. An anatomical study of the acoustic fibers is reported by Fuse (24), who describes the striæ acusticæ in man. These fibers, he finds, do not completely cross to the opposite side of the brain, although the relative amount of the crossing is not known.

Vision.—Of the sensory areas of the cortex, that for vision has been the most investigated, for both in animals and in man deficiencies in visual ability are relatively easily determined. The apparent definiteness of the facts has, however, led to superficial conclusions, as has been indicated above, and it is now recognized that the earlier views of the cortical localization of visual processes are as inadequate as those of motor localization. That the calcarine type of cortex is the part to which the impulses originating in the retina go is now generally believed, and this view has received confirmation for the brain of the dog by the researches of Minkowski (43, 44) who concludes; (*a*) that this is the only part of the cortex which primarily receives the visual impulses, and (*b*) that each occipital lobe is connected with the corresponding parts of the eyes. In monkeys Franz

(20, 21, 22) has shown that the destruction of the lateral, or convexity, portions of the occipital lobes does not produce a blindness, but that it produces inaccuracies of visuo-motor reactions. The latter results, which appear out of harmony with much previous work, are in harmony with the conclusions of Minkowski (44) that on the convexity of the dog's brain there is an optical motor center. In the brain of the gibbon, however, Mott, Schuster and Sherrington (45) found the optico-motor centers ranged along the calcarine fissure, but their results are not necessarily antagonistic to those of Franz and Minkowski.

The paper by Savage (56) is an attempt to prove by reference to a schematic diagram that there is an "actual existence" of nine conjugate and fusion centers in the brain. The confusion of "must be" or "I assume" with "is" is a not uncommon fault of certain strict localizationists, and the article is cited here as an extreme example of some current methods of thought and localization methods. Two somewhat similarly discursive and inconclusive articles by Dufour (14) and by Brückner (9) may also be mentioned; Dufour elaborating an hypothesis of monocular and binocular scotomas, and Brückner, from insufficient data, concluding that light adaptation is due to central processes in the visual path.

Two interesting cases are described by Redlich (50); one with left hemianopsia (later complete blindness), and the other with right hemianopsia, failed to appreciate their defects. These facts are of interest in connection with supposed perceptual centers in the cerebral cortex.

Much dispute regarding the cortical localization of visual sensations has arisen because of the believed-to-be impossibility of separating effects from the cortex and from the underlying fibers. Henschen (29) believes that this is possible, and, although he brings forth no new evidence, he asserts that sufficient facts demonstrate this. We know, however, that there are cortical fibers as well as cortical cells and that at least some of the fibers are continuous with the subcortical fibers. Since all the facts may be accounted for as von Monakow has done, and only some of them as Henschen does, it is more reasonable to believe in the explanation of the former.

The brain of the deaf-dumb-blind patient described by Gans (25) showed a decrease in the number of fibers in the occipital cortex and a decrease in size of the corpora geniculata externa. Although the case of Hoppe (31) was complicated, clinically and anatomically, by cerebellar and pontine disturbances, visual defects were present

and these were associated with lesions of the corpora quadrigemina. The clinical symptoms in the patient described by Winkler (62) are of great interest, since vision for light was retained but recognition of shapes was lost. This was accompanied by destruction of the left pulvinar, including the ventral and medial nuclei of the thalamus. However, the conclusion that the recognition of shapes is due to light impulses elaborated by connections "prepared within the thalamus, [which] become able to communicate to definite portions of the cortex the data enabling the latter to recognize shapes," is another example of the assumption that the cortical cells are of the nature of homunculi, or individual minds, which do the seeing.

Association.—Attempts to establish a relation between certain parts of the brain and the so-called higher mental processes have been numerous and the frontal lobes are the parts usually selected. That these parts are important is evident from the clinical and experimental evidence, but there are certain facts which negative the conclusion that they are the "seat" of the intellectual faculties. In dogs, Feliciangeli (18) found little change following the unilateral extirpation of the prefrontal region, but when the lesion was more extensive there resulted slight, but temporary, sensory disturbances on the opposite side of the body with a tendency to manège. Ascenzi (1) describes a case of an illiterate man who, with an extensive destruction of substance in the right prefrontal region, exhibited no notable changes in mental capability, except that of slight diminution of the "imaginative power and of phantasy and intuition." It is usual to find mental disturbances of a more marked character associated with frontal lobe lesions, and these have been found by Constantini (11), by Curti (12), by Donath (13), by Edes (15), by Mingazzini (41), by Roncorini (51), by Serog (55), and by Sullivan (58). Many of the cases described by them are not clear cut, and the mental symptoms are not always the same. Thus, for example, the patient of Constantini was arteriosclerotic and although his mental condition was not normal it is not clear that it was different from that of a patient with cerebral arteriosclerosis without special frontal lobe lesion. Curti's patient, in whom the right frontal lobe was destroyed, had classical symptoms of frontal lesions, and likewise Donath's patient, in whom a tumor on the left side also produced anarthria and aphasia for three languages, which, after operation, the patient partly relearned. Because of the extension of the effects of the original lesion the symptoms in the case described by Mingazzini were complicated with motor phenomena and in some respects the

symptom-complex resembled that in cerebellar disease. The symptomatological similarity of frontal lobe and cerebellar lesions has frequently been remarked. Serog, and Roncorini discuss in a more general way the relation of frontal lobes to mental states; both conclude that there are no special symptom-complexes associated with frontal lesions. Roncorini holds a view similar to the diaschisis hypothesis of von Monakow, and Serog maintains that there is no reason to believe that the "intelligence" is situated in the frontal lobes, and that "the activity of the whole cerebral cortex must be assumed as the foundation of intelligence," but that the frontal lobes may play a special part in the associations.

Although frontal lesions are most often accompanied by mental disturbances, Guilarowsky (27) believes we must not omit from consideration the temporal lobes.

The impetus to the study of the aphasias is still evident by numerous contributions, which will be considered in another review. It may, however, be mentioned that Marie (38) criticizes Heilbronner, and Dejerine[1] for speaking of his view as the "dementia" view. Marie has, however, written: "Chez les aphasiques il y a une diminution tres marquée de la capacité intellectuelle en générale." Moreover, he disclaims any generalized hypothesis regarding aphasia, limiting himself to the recording of facts, which, among other things, demonstrate that a lesion in the third frontal convolution, not involving other structures, is not accompanied by a true and persistent aphasia of the Broca type. A relation of the insular area to speech function has been believed in by many neurologists, but Manoia (37) reports a case in which this part was affected without producing any speech disturbance, and he concludes that no fibers carrying impulses for articulation or speech understanding pass by the gyri longi posteriores insulæ.

Cerebrum and Cerebellum.—The cerebellum, as well as the cerebrum and its gray masses, sends impulses to the motor cells in the spinal cord, and it is connected efferently and afferently with the cerebrum. The exact functional value of these connections is not understood, but it is believed that the cerebral activity is controlled by the cerebellar and the cerebellar by the cerebral. By noting the currents of action Beck and Bickeles (4) have found that when the motor cerebral cortex is stimulated the cerebellum is affected, the influences being more active on the opposite side. A similar result

[1] And, in a private communication, the reviewer, who had used the term, but who also wrote that "the relation of aphasia to dementia or to mental deterioration . . . is to be settled only by definition" (PSYCHOLOGICAL BULLETIN, 1911, 8, 115).

was found when the cerebellum was stimulated and the electromotive condition of the cerebrum was noticed. Rossi (53) has obtained confirmatory results by a different method, for he has observed that the stimulation of parts of the cerebellum increases the excitability of the motor cerebral cortex on the opposite, but not on the same, side. Rossi (52) also found that the irritability of the motor cortex was decreased after hemiextirpation of the cerebellum in dogs, and this decreased excitability continued during the period of time that the symptoms of cerebellar insufficiency persisted. When compensation (for the cerebellar loss) took place the motor cerebral cortex became more irritable. It would appear, therefore, that the cerebellar impulses act as a check upon, or as an activator of, the cerebral.

Histological Studies.—Two histological studies of functional interest may be mentioned. Mellus (40) has compared the cortex in Broca's center and in the temporal lobes on both sides of three brains and has found the left deeper. Marinesco and Goldstein (39) have made a careful study of the hippocampal region, and have drawn therefrom certain physiological deductions regarding the cortical localization of smell and taste sensations in this region.

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CEREBELLUM AND BRAIN-STEM

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Several methods have recently been employed in the study of the functions of the cerebellum and their localization. Preisig (6), from a thorough histological examination of the nervous system in a case of congenital or very early atrophy of the cerebellum, with idiocy and defect of locomotion and other motor functions, reaches the conclusion that the mental defect need not be connected with the condition of the cerebellum, since the cerebrum also was affected. There had been a meningeal inflammation with involvement of the adjacent cortex of both cerebrum and cerebellum. The motor defects shown by the patient can be attributed to the condition of the cerebellum, and the mental defect to the cerebrum. This case throws light on similar cases in the literature, in which idiocy appeared in cerebellar atrophy, but in which the cerebrum was not histologically examined. Secondary atrophy was found in several structures connected with the cerebellum on the afferent side, such as the middle peduncle and pontine nuclei, the olives, the column of Clarke, direct cerebellar tract and inferior peduncles. On the other hand, little change was visible on the efferent side, namely, the dentate nucleus, superior peduncles and red nucleus.

Rothmann (7) extirpated limited portions of the cerebellar cortex in dogs, and found evidence of localization of function, inasmuch as destruction of the cortex of the quadrangular lobe affected the action of the fore leg, and destruction of the semilunar lobe, the hind leg, while destruction of the vermis affected the trunk muscles. In this last case, the effect was contralateral and is described as a paralysis, but in the former two cases the limb affected was on the side of the lesion, and the effect was an apparent disturbance of the sense of position.

Löwy (4), by cutting the nerves of the hind limb in a young animal, caused delayed myelinization in the median posterior lobe of the

cerebellum, and concluded that this part of the vermis is connected with the hind limbs.

Beck and Bikeles (3) stimulated various peripheral nerves, having first connected the surface of the vermis to a galvanometer, so as to detect action currents aroused in the cortex of this part of the cerebellum by impulses coming in from these peripheral nerves. An action current in the vermis under these conditions would be evidence of an afferent pathway thither from the nerve stimulated. In fact, action currents were in evidence with sufficient frequency to indicate such a connection, though they appeared somewhat less regularly in the vermis than in the motor area of the cerebrum, which was similarly examined for purposes of comparison. No evidence of sensory localization within the vermis was obtained, since action currents appeared in any part of it, no matter whether the fore or the hind limb was stimulated. Evidence of a path to the vermis from the vagus nerve was also obtained by this method.

The same authors (2) used the method of action currents in a study of the reciprocal connections of the cerebellum and cerebrum. Not getting satisfactory results from the usual electrical stimulation of the cortex, they tried a thermal stimulus, consisting of a temperature of 55°–58° C., applied in the same manner as in temperature sense experiments, and found this to be very effective. When they thus excited the motor cortex cerebri, they obtained action currents in the cortex of the cerebellar hemispheres. These action currents, without being absolutely regular, were still very frequent—most frequent in the side of the cerebellum opposite to the part of the cerebrum stimulated, but fairly frequent also on the same side as the stimulation—indicating therefore both a crossed and an uncrossed path from the cerebral to the cerebellar cortex. When, instead of the motor area, the region behind this was stimulated, there was little sign of effect on the cerebellum. When, finally, the experiment was reversed, the cerebellum stimulated and the cerebrum examined, action currents appeared less frequently than before, but still frequently enough to indicate a path leading from the cerebellar to the cerebral cortex. The currents appeared most frequently in the motor area, but sometimes also behind it.

The book by André-Thomas (1), now translated, gives a very useful account of present knowledge regarding cerebellar functions. Part I. is devoted to an exposition of facts, including the anatomy and connections of the cerebellum, the results of extirpation and excitation experiments (including many of the author's own), and

the symptoms of cerebellar disease in man. Part II. is devoted to interpretation. Gall's theory of a sexual function of the cerebellum is rejected as based on a few coincidences, which are more than offset by negative instances. The theory that this is an organ of intelligence is also based on no real evidence; and, though many sensory pathways lead into the cerebellum, especially perhaps from the muscles, the evidence is against the cerebellum being the organ for conscious sensation or perception. Even the vestibular nerve, which has often been regarded as having its center in the cerebellum, has probably a cerebral center, and is not, as a matter of fact, connected very richly with the cerebellum. It is true that a few fibers find their way from this nerve into the base of the cerebellum, and also that many fibers pass between the cerebellum and the terminal nucleus of this nerve (nuclei of Deiters and Bechterew and triangular nucleus), but these last fibers are found to be efferent, enabling the cerebellum not to be affected by the vestibular nerve, but to affect its terminal nucleus and the motor paths that lead out of the latter. Thus is explained the curious similarity between the symptoms of injury to the vestibular nerve or its end-organs in the inner ear, on the one hand, and the symptoms of cerebellar injury on the other. Since both act, in part, on the same lower mechanisms, their actions are similar though not identical. The vestibular nerve contributes to the maintenance of equilibrium against impressed movements, while the cerebellum aids in the equilibrium of active movements, both reflex and voluntary (pp. 196–197).

The author rejects some of Luciani's generalizations regarding cerebellar function. The muscular *asthenia* after cerebellar lesion, which led Luciani to infer a sthenic function for the cerebellum, is not confirmed as a fact by André-Thomas; and the *atonia* is not general, but affects only the muscles most concerned in maintaining equilibrium. Luciani's *astasia*, or tremor in muscular contraction, due to a want of fusion of the elementary contractions, is fully accepted by the present author, who adds, as a further general symptom of cerebellar lesion, a *dysmetria*, or lack of proper measure in the force of muscular contraction. The lack of measure shows itself as an excess of movement. The legs are lifted too high, the trunk pushed too strongly to one side or the other, and the excess of upward and backward thrust, in mounting stairs, is likely to cause the subject, whether man or dog, to fall over backwards. The function of the cerebellum is thus to exert a steadying and moderating influence on movements initiated by the cerebrum or by reflex paths.

A certain degree of localization is admitted by the author, largely on the basis of the comparative anatomy of the cerebellum. The vermis, phylogenetically older, is closely related to the cord and bulb, and concerned with bodily equilibrium. The cerebellar hemispheres, closely connected as they are with the cerebrum, are probably related to the control of voluntary movement. The cortex of the cerebellum is in close relation to the afferent paths, while the ganglia in the interior (dentate nucleus, nucleus of the roof, etc.) are in direct relation to the outgoing paths.

While, certainly, very much remains to be learned before the functions of the cerebellum can be understood, this work perhaps conveys as clear and sound a conception of the matter as can be expected at the present moment.

The physiology of the striatum and thalamus is still extremely confused and confusing. Some little evidence has accumulated, first and last, for a heat-regulating center in one or the other of these structures, in warm-blooded animals. Nikolaides and Dontas (**5**) have applied an ingenious method in studying this function. When a warm-blooded animal is subjected to high external temperatures, the rise of body temperature is combated, in part, by polypnea, or rapid breathing. Placing a dog in a warm chamber and raising his temperature till polypnea resulted, these authors then transected the brain stem at some level above the respiratory center. The shock of operation caused a temporary inhibition of breathing, but, if the section was high enough to leave the striatum or part of it in connection with the bulb, the polypnea returned, whereas if the section severed the striatum from the bulb, there was no return. This heat-regulating reaction was therefore dependent on the striatum, though the authors add that the thalamus seemed to have some influence in the matter.

Madame Vogt (**8**), reviewing recent cases of human lesion of the striatum, generalizes as follows: The combination of symptoms which appears when injury is limited to this organ does not include motor paralysis, nor disturbance of sensibility, nor diminution of intelligence; but it does include spasms of various muscles, athetoid movements, rhythmic oscillations, associated movements, spasmodic laughter and weeping. Apparently the whole musculature is represented in the striatum. The author's interpretation of the spastic phenomena is that they arise from the removal of an inhibitory influence normally exerted by this organ. Its internal structure, with the variety of cell-forms shown, indicates that it is by no means a simple relay

station—such a station would call for only one type of cells—but affords provision for complicated switching operations.

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PSYCHOGALVANIC, CIRCULATORY AND RESPIRATORY PHENOMENA

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The only important contribution to the literature of the psychogalvanic phenomena in the last two years is that of Wells and Forbes (23). This paper deals in a discriminating way with the numerous difficulties of technique, method and interpretation—difficulties which the majority of experimenters in this field have apparently failed to appreciate. The authors point out the impossibility of using metallic electrodes, and the fact that the so-called non-polarizable calomel electrodes are only relatively non-polarizable, and do not necessarily assure freedom from electrode currents. Pairs of electrodes tested gave deflections of the galvanometer (d'Arsonval) up to 400 mm., from the potential difference of the electrodes alone; but it was found possible with care to reduce this difference to a negligible quantity.

As a result of their experiments, Wells and Forbes conclude that variations in both body resistance (when a battery is used) and potential differences between the two skin areas employed are involved in the production of galvanometric deflections. The potential dif-

ferences are probably due to activity of the sweat glands, although vaso-muscular action currents are not excluded.

Although using the d'Arsonval galvanometer, Wells and Forbes note that it should be replaced by improved instruments. Sommer (18) emphasizes the fact that the string galvanometer must be used in psychogalvanic work. Yet nearly all of the investigators cling to the inadequate d'Arsonval. Worse yet, most of them still use plate electrodes. For example, Klasi (8) uses brass, Moravcsik (13) nickel, and Radecki (14) zinc plates, and obtain accordingly results of conventional valuelessness.

A method of differentiating the effects of change in potential and change in bodily resistance described by Albrecht (1) depends on simultaneous registration through two circuits, one of high, the other of low, external resistance. The description is too brief to be quite clear.

The mass of experimental literature on respiration and circulation is so enormous that it is not possible here to do more than note a few typical articles along lines of most interest to psychologists.

Weber (22) criticizes O. Müller and his school for omitting respiration registration in plethysmographic work, and shows from specific experiments that the respiration waves in plethysmographic records do not indicate the actual fluctuations in respiration. Leschke (9) gives a review of literature dealing principally with the work of Weber. Frankfurther and Hirschfeld (3) report their attempt to find the effect of music and consonant and dissonant chords on the arm plethysmogram. They show a distinct lowering of the volume curve for all cases with normal patients, although they state that certain hypnotized patients showed the reverse effect with agreeable chords. Sikorski (16) describes an investigation of the relation of "mental states" to sphygmogram and pneumogram form and to expression of face and attitude. He believes that the "attentive" state is characterized by an equilibrium of arterial innervation; emotional states by preponderance of the tonic or the depressor. The sphygmogram form has distinct individual characteristics, like the handwriting, the speech, etc. Strassburger (20) describes a new recorder for plethysmographic work, on the principle of a gasometer, which has the advantages of the piston recorder without the friction. Hoffmann (5) describes a device for recording the pulse with the string galvanometer, embodying the principle of the simple magnetic telephone. (A telephone receiver has been used for this purpose by several persons.)

Lombard (11) reports a method of observing superficial blood vessels under a microscope by using a drop of oil or glycerine to render the skin transparent.

Coming now to live issues: Hofbauer (4) finds effects of lowered blood pressure on respiration, which make it seem probable to him that the affective modifications of respiration are due to blood pressure changes, although he does not attempt to explain the mechanism. Hooker (7) concludes that carbon dioxide relaxes the tone of arterial muscle when acting directly thereon, which seems to agree with the results of Stewart (19) who finds forced breathing for from six to nine minutes decreases the flow of blood through the hand. Sollmann and Pilcher (17), on the other hand, find that accumulation of carbon dioxide in the blood causes reflex constriction of arteries cut off from its local action. The number of investigations on the effects of carbon dioxide, and of extracts of ductless glands on automatic processes is very large.

Important experiments on the effects of muscular activity on circulation have been carried out by Hooker and by Lowsley. Hooker (6) investigated the effect of exercise on venous pressure, finding a rise of from fifty to three hundred per cent. after from eleven to fifty-two minutes exercise on a stationary bicycle. Lowsley (12) measured the systolic and diastolic pressures and the pulse pressure and rate during bicycle riding, and after various moderate, vigorous, fatiguing, and exhausting games and athletic tests. He found in all cases rise in pressure and rate, the height of systolic and pulse pressure varying with the vigor and exhaustingness of the exercise. The practical conclusion is that "field" events are safer than "track" events and rapid games, from the point of view of strain on the circulatory system.

In connection with effects of muscular exercise on the circulation, it is of interest that the experiments of Aulo (2) seem to him to indicate the decrease of vagus tone as the primary cause of heart acceleration.

Linhard (10) found a change in respiration with the seasons in the cases of six subjects. In the summer the respiration frequency and alveolar carbon dioxide tension are higher, and the expiration volume lower than in winter. This variation the author thinks is due to the variations in the light, because he found that subjecting the subjects for an hour or less to arc-light baths in January brought about the respiration condition characteristic of summer.

Tullio (21) describes a method of registering respiration by means

of a cord running over pulleys from a weight on the chest or abdomen of the semi-reclining subject, to the writing lever, with a small weight below the lever to keep the cord taut. Regen (15) has been able to register the respiration of insects by confining them in a perforated test tube, with a "needle" pressing at one end against the insect's abdomen, and at the other against the short end of the writing lever. This method will doubtless be of value to the insect psychologist.

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THE PHYSIOLOGY OF NERVE

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An able paper by Lillie (22) offers perhaps the clearest idea yet given of the nature of the nervous impulse. The cell membranes of irritable tissue are when unexcited only semi-pervious to the passage of ions, and the process of stimulation consists (according to the Nernst theory) in an increase in the permeability of the membrane. This increase accompanies, perhaps is caused by, a depolarization of the membrane at the same point. Phase boundaries in general are the seat of electrical forces, and by the plasma membrane, which is the essentially irritable part of the cell, and which "in spite of its extreme thinness is apparently less permeable than the most impermeable of the precipitation membranes thus far known," the protoplasm is sharply delimited from its surroundings. Cations probably pass through even when the membrane is unstimulated, but not the accompanying anions. "The possibility that the cation concerned in the phenomena of demarcation and action currents is no other than the hydrogen ion must be regarded as experimentally substantiated." "The most probable explanation of the action current . . . is that the plasma membrane undergoes during stimulation a sudden increase in its permeability" so that all ions (even the anions) are now free to diffuse from the cell: and this works to decrease an already existing polarization of the membrane. Thus "the wave of excitation is accompanied by, or equivalent to, a wave of depolarization, *i. e.*, of increased permeability . . . and it is to be assumed that this region, acting then as a cathode, influences electrically the adjoining regions, depolarizing these in turn and causing a corresponding increase in permeability; in this manner the effect is propagated along the membrane at a rate which in any particular case will evidently depend on the sensitivity or quickness of response

of the tissue." In a second paper (23) Lillie further discusses the same theory (vide p. 393): and shows that "anæsthetics are substances which render the plasma membrane of the irritable tissue more resistant than normally to changes of permeability." McClendon (27) similarly finds that during muscular contraction there is an "increase in permeability of some structures within the muscle to anions (since the muscle appears already permeable to certain kations)." Eucken and Miura (9) discuss the Nernst theory, approving the modifications of Nernst's original formula which have been suggested by Lucas and Hill. They say that the break-stimulation is still not satisfactorily explained. Wilke (40) and Wilke and Atzler (42) offer what they call the "acoustical theory" of nerve transmission, *i. e.*, that the nervous impulse is a physical deformation wave which travels along the nerve substance. In spite of the reactionary quality of this theory several aspects of the subject are ingeniously handled; and the authors assert that a deformation wave travelling along a cylindrical mass of gelatine exhibits an electrical phenomenon comparable to the action current of nerve, and even that electrical stimulation of such cylinders will produce vibratory movements in them. They claim also to have demonstrated fine physical oscillations in frog nerves as a result of stimulation with non-polarizable electrodes.

This question of rendering nervous processes visible to the eye or to the camera still engages attention. Wilke and Atzler (41) tried to produce stationary waves in a nerve fiber and to photograph them in the ultraviolet microscope (after Höber), or else to see them by the aid of intravital staining processes. They have so far failed, as Auerbach (2) has also failed in a similar attempt. Auerbach reports photographing with the ultraviolet microscope interesting *structural* features of axones. Schwartz (30) finds that at least live axis-cylinders are differently susceptible to intravital stains at anode and at cathode (Bethe's *Polarisationsbild*). This makes it possible to study with the eye some phenomena of nerve excitation.

Tigerstedt (32) states that the fatiguability of medullated nerve fibers is easily demonstrated, specially in low temperatures: in fatigue the latent period is lengthened. Thörner (31) reports the same. Haberlandt (17) finds a reduced rate of transmission in fatigued medullated axones (frog): the axones showed rapid recovery. Wedensky (39) found no fatigue of motor nerve during several hours of constant stimulation. Maydell (26), using a series of induction shocks to stimulate the sciatic nerve (frog), found a steadily increasing

latent time for the heterolateral gastrocnemius reflex: but the height of this contraction increased at the same time.

Hill (18) finds no temperature change due to the transmission of a nervous impulse, and shows that if such change exists it cannot exceed one hundred millionth of a degree C. "for every single propagated disturbance. . . . This suggests very strongly, though of course it does not finally prove, that the propagated nervous impulse is not a wave of irreversible chemical break down, but a reversible change of a purely physical nature." Thörner (31) finds that nerves fatigue less readily in high temperatures than in low, but they suffocate (in the absence of oxygen) more readily in high temperatures than in low. Both phenomena are probably due to accelerated oxidation and diffusion processes in the higher temperatures which abbreviate the refractory stage. Verzár (35) studies the electric current produced in a nerve when two portions of it are brought to different temperatures. When the point of higher temperature is 20° C. or less the current flows (within the nerve) from the cooler to the warmer point. Ganter (13) finds that for temperatures between 0° and 30° C. the rate of propagation of the nerve impulse is approximately proportional to the temperature. The rate of transmission at $(t + 10)°$ divided by the rate at $t°$ (Van 't Hoff's quotient) gives on the average 1.75: a value which agrees closely with the quotients obtained by Lucas and Maxwell.

Bramwell and Lucas (3) study whether the refractory period of nerve is due to the propagated impulse or (perhaps) to some local effect of the electric current at the seat of excitation. They conclude "that the diminished excitability which follows an effective stimulus is entirely due to the passage of the propagated disturbance over the tissue, and is not caused to any measurable degree by a local action of the exciting current." Vészi (38) states that the action current from an induction shock imparted to a nerve during the phase of positive after-discharge (*positive Nachschwankung*), produced by previous repeated induction shocks, is very much reduced. The reduction can be due only in very small part to fatigue of the nerve. Dittler (7) partly confirms Vészi, but believes that the conditions are more complicated than Vészi describes them. From his studies with cinchonamin Ellison (8) concludes that "the injury current and the negative variation are independent phenomena"; and that "a negative variation does not necessarily accompany a nervous impulse." This latter result is disputed by Dittler and Satake (6) who find that in cinchonamin poisoning there is never

nerve action (muscular contraction) without action current (negative variation). They point out how Ellison was probably misled.

Lucas, in an important paper (24), shows "that a stimulus falling within the refractory period set up by a previous stimulus does not prolong the refractory state" (contra Fröhlich): but it *may* serve to increase the response provoked by a subsequent effective stimulus. The above holds true for either nerve or muscle, although the refractory period of nerve is a different thing from that of muscle. "If two stimuli are sent into a nerve at such an interval of time that the second produces a small second response in the muscle it is possible by interpolating a stimulus between them to abolish the second response" (simplest form of the Wedensky effect). "The abolition of the second response results only if the interpolated stimulus is so timed that it falls outside the refractory period of the nerve and sets up in the nerve a propagated disturbance which fails to excite the muscle." The Wedensky effect depends on a property of the myoneural junction (similar to that of the synapse of the central nervous system) "namely a resistance to conduction greater than that of the continuous axon." But one still wonders why the interpolated stimulus does not augment rather than inhibit the effect of the succeeding stimulus. Adrian and Lucas (1) find two kinds of summation—the "summation of local excitations" set up by the electrical stimuli, and the "summation of propagated disturbances." The latter occurs whenever propagated disturbances encounter a "region of decrement," *i. e.*, of reduced conductivity such as a synapse or myoneural junction. "The summation of propagated disturbances commences with intervals between stimuli slightly greater than the relative refractory period, passes through a maximum, and disappears as the interval is increased. . . . The summation of propagated disturbances depends on the falling of each successive disturbance in the supernormal phase of recovery after its predecessor." The two Lapicques present a brief study of summation (20) and a "law of summation" (21). Foà (11, 12), Buytendyk (4), and Fahrenkamp (10) have studied the periodicity of motor nerve impulses (by means of the string galvanometer). Foà, like Sherrington, believes that the rhythm of motor impulses originates in the spinal centers. Vészi finds that the "all or nothing law" holds for all modes of stimulating the strychnine frog (36), and that it holds generally of fresh and uninjured nerve fibers; but it does not hold of a nerve fatigued, as by faradic stimulations (37).

Magnanígo (25) finds that chloroform diminishes only slightly

the excitability of nerve trunks: chloral hydrate and chloretone have no effect on the motor fibers of peripheral nerves. Of the various drugs experimented on ether is the only one which was found to be capable of abolishing the conductivity and "consequently" the excitability of peripheral nerve trunks. Garten (16) found that a 1 : 1,000 solution of curare produced no change in the rate of propagation nor in the negative deflection of nerve impulse in medullated fibers. Ishikawa (19) found that the irritability of nerves is generally decreased when they are immersed in a hypotonic solution, but increased in a hypertonic solution. The rate of propagation of the nervous impulse is a function of the irritability of the nerve (cf. Lillie, 22).

Piper (29) discusses the action current of the retina, criticizes the theory of Einthoven and Jolly, and presents a theory of the electrical phenomena of the retina. Garrey (14) believes that there is in the heart a conducting tissue which is more sensitive to compression than ordinary motor nerves or skeletal muscles, also (15) that "compression establishes in nerves a condition as a result of which the passage of one or more impulses renders it [them] refractory to a succeeding impulse." Meek and Leaper (28) also study the effect of compression on nerve conduction. Carlson (5) finds that physically stretching a nerve decreases its rate of conduction. Tschagowetz (33) has an interesting study of "electrical sleep," *i. e.*, the sleep induced by repeated induction shocks (in the ascending direction) to the spinal cord: all reflexes are augmented, much as in strychnine poisoning. Maydell (26) used this "sleep" to obtain certain reflexes.

Verworn's valuable paper on the general topic of irritability (34) is a German translation of his article *Irritabilité* in Richet's *Dictionnaire de Physiologie.*

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RECENT CONTRIBUTIONS TO OUR KNOWLEDGE OF THE NEURONE

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Recent investigation of the neurone has been largely along four lines, viz. (1) to ascertain the method of interneuronal connection; (2) to determine the relations of the neuroglia to the cell body and axones; (3) to determine the actual morphologic entities in the cell body and axone and so free the nomenclature from unnecessary and reduplicated terms; (4) to determine the morphogenesis of the neurone and its various structures.

1. *Interneuronal Connection.*—There has been considerable investigation directed to the solution of the structure of the axonal terminations, called by Held *Endfüsse*, and their relation to the cell body on which they terminate. These have recently been studied by Kató (10) in the spinal cord of the cat. He found that an axone divided into several parts, each ending in a bulbous enlargement applied to different parts of the cell body of another neurone and also to its dendrites, but not to the axone except at the cone of origin. Kató divides these terminations into three types. The most numerous type consists of a peripheral loop with crossing fibrils embedded in a plasmatic basis. In the second type one of the terminal branches of the axone divides at its entrance to the *Endfuss* into several twigs like the neurofibrils of the cell, forming a net-like structure, the whole mass being generally elliptical in shape. In the third type, also elliptical, the terminal branches of the axone split into fine fibrils which possess small granules. The *Endfuss* in general seems then to consist of a plasmatic matrix in which are embedded the fine fibrils of a terminal branch of an axone. The plasmatic portion of the termination resembles somewhat the cytoplasm in reaction and there is a seeming fusion of the two. In spite of this apparent fusion the fibrils of the *Endfuss* have no connection with the endocellular fibrils of other neurones, and the two sets of fibrils have different chemical characters and reactions. This view of the non-continuity of these terminations and the cells is concurred in by Ramon y Cajal, Meyer and others. If this represents the true relation between the axones and the cell bodies then Held's *Endfüsse* are rather in favor of the neuronal entity than against it.

Lenhossék (14) has investigated the termination of the oculomotor

nerve in the ciliary ganglion of reptiles and finds that the fibers end as a network of fibrils in a disc closely applied against the cell, but staining differently. He found no evidence of the connection of the disc fibrils with the endocellular network. Carpenter also describes in the ciliary ganglion of the bird a calyx-like expansion of the oculomotor axone around one side of the ganglion cell but found no evidence of a relation of continuity.

2. *Neuroglia.*—There seems to be at the present time a renewed interest in the neuroglia, especially in its relations to the axones and cell bodies and its function. Marano (**18**) investigating these relations in the spinal cord of the teleosts, finds that the glia in no instance simply separates the nerve elements, but in all cases presses into the myelin sheath and forms a supporting myelinic skeleton. In the case of the nerve cells the glia fibrils extend into the interior of the cytoplasm and form an endocellular reticulum reaching even to the nucleus. In addition there is also a pericellular glial network. No suggestion is made as to a possible function, but if such a glial relationship exists it may possibly be expressive of a nutritive or secretory function as has been suggested recently by some investigators (**21**) who have described granules, apparently of secretion, in the glia cells and consider the neuroglia, therefore, more of a secretory structure than a supporting one. The recent work of Paladino (**22**) is quite in harmony with the observations of Marano. He also finds that this endocellular penetration of the glia cells is more marked in senile than young cells. While several investigators have recently described somewhat similar findings it seems to the writer that we are here probably dealing either with artefacts or are misinterpreting the appearances as to this seeming penetration of the nerve cell and axone by glia cells. At any rate further work is necessary for the complete elucidation of this matter.

3. *Morphologic Entities.*—If the recent work of Maccabruni (**17**) prove correct, we shall be compelled to revise our conception of the structure of the axone. Heretofore we have thought of it as a mass of parallel neurofibrils with a perifibrillar matrix interrupted possibly at the nodes of Ranvier. Maccabruni by a silver reduction method finds bacilli-like rods in the medullated axones of fish, amphibian and man, arranged parallel to their axes, but not in non-medullated axones or in medullated axones before their sheaths are assumed. These rods do not stain by the usual methods for mitochondria (see infra). In spite of the fact that he vigorously contends that these rods are not imperfectly stained neurofibrils, the fact that he has not

been able to stain both rods and fibrils in the same axone leaves much doubt as to the existence of these rods as distinct entities. While some recent investigators have contended that the axonal neurofibrils are artefacts, the preponderance of evidence is against this view and in favor of their existence as morphologic entities.

The cell body has proved an attractive field for investigation recently as well as in the past. It is very unfortunate, however, that so great confusion should exist in the nomenclature of the neurone from the multiplicity of names for apparently identical structures. Probably there will never be a satisfactory nomenclature until it becomes possible by stains and chemical processes to differentiate in one and the same cell all the described morphologic characters. Even then the possibility exists that our morphologic differentiations may be artefacts, but they still would represent at least differences of material.

There have been described in the cell body of the neurone as morphologic entities a number of structures to each of which several names have been applied, as the *neurosomes*, *neurofibrils*, *mitochondria*, *Nissl's bodies*, the *canalicular system*, *Golgi's endocellular net*, *Binnennetz*, *chondriosomes*, *chondriocontes* and *chromidial apparatus*.

The *neurosomes*, first described by Held, have been considered as artefacts by some, or imperfectly stained neurofibrils by others. Cowdry (5), in a recent study of the ganglion cells of the pigeon, thinks that there are two kinds of neurosomes, one of which is the more variable in size and irregular in shape and, staining with erythrosin, occurs densely crowded together with its fellows in the axone hillock. The nature and significance of these he was unable to determine, but believes that they are not artefacts because he has been able to demonstrate them after using a considerable number of different fixatives. On the other hand the more rod-like granules he considers *mitochondria*, as their staining affinities are similar. These latter true neurosomes are found extending out into the axone and dendrites, and are well shown by the iron-hæmatoxylon method.

The *mitochondria* are protein granules originally demonstrated by Benda and since studied by many observers in various kinds of cells. They are thought to be of importance in cell metabolism as many of the chemical changes in the cell occur in them, and they are closely associated with the most active part of the protoplasm, the perinuclear region, and are probably formed under the influence of the nucleus. In some cases threads are formed from them called the chondriomitome fibrils. They are probably identical with the

chondriosomes, chondriocontes and chondriomites of various observers.

Nissl's bodies, known also as tigroid substance, or chromatophile substance, have been shown not to be artefacts, and to be morphologically independent of the neurosomes, neurofibrils and mitochondria. Nothing new as to their function has been disclosed.

The *canalicular system*, apparently a series of branching canals in the cytoplasm of certain nerve cells, was first described by Holgren in ganglion cells, who claimed that the canals contained the branching processes of other flattened cells applied closely to their periphery and forming the *trophospongium*, from their supposed nutritional function.

This system has been studied by Kopsch, Bensley, Cowdry and others, and appears as clear colorless spaces by some methods of fixation and staining, while they are colored purple or brownish black by other methods. The fact that they stain at all would indicate that they were not empty spaces but possibly contain some fluid or semifluid substance. Similar spaces found in the cells of glands are considered as channels for secretions. Cowdry divides this canalicular apparatus, according to its arrangement, into the diffuse, eccentric and circum-nuclear type, which types he claims occur with considerable constancy.

The diffuse form, according to Cowdry, occupies almost the whole extent of the cytoplasm in large ganglion cells; the eccentric consists of a small collection of canals, mostly on one side of the nucleus; the circumnuclear is a rather close network near the nucleus and found in the small cells. He considers this canalicular system as morphologically distinct from the mitochondria, Nissl's bodies and neurofibrils, as he is able to differentially stain them in the same cell, and further believes that it is identical with the *spiremes* of Nelis, the *Binnennetz* of Kopsch and the *Saftkanälchen* of Holgren. Bensley and Cowdry consider this system as an osmotic mechanism more or less continuously varying in the living cell.

4. *Morphogenesis.*—The multicellular origin of nerve cells is still maintained by Fragnito, Copobianco, Held and others, in spite of the work of Harrison (7), Lewis (16) and Burrowes, which clearly showed the falsity of this conception. Marcaro (20), on the ground of recent experiments, maintains, as against multicellular origin, that Held's interneuroblastic connection and plasmodesms are artefacts due to pyridin fixation and Cajal believes that if such connections exist at all it is only to a slight extent. The anastomoses which form when neuroblasts are growing *in vitro*, as Lewis and others have shown,

make it seem not unlikely that similar anastomoses may occur in the body and that here too they may be transitory and changing.

Marcaro believes that the neuroblast is a discrete cell at a very early stage and doubts Cajal's statement that there is an apolar stage between the germinal cell and the bipolar neuroblast. He believes that the neuroblast can be early identified by the criteria of bipolarity, an elongated nucleus rich in chromatin and a cytoplasm containing neurofibrils. At a very early stage neuroblasts have two processes, one short directed centrally and the other longer toward the periphery. Even at this early stage delicate fibrils can be shown by silver reduction methods completely differentiated and entirely independent of one another. The process of differentiation begins, according to Marcaro, in the central process, extends around the nucleus and continues into the peripheral process. He finds the neurofibrils present as early as a fifty hour chick, extending throughout the cytoplasm in a net-like arrangement, and nowhere isolated fibrils such as Besta claims. The fibrils increase rapidly and the growth is from within out, each cell acting as a genetic unit.

This is contrary to the observations of Besta, Fragnito and Held. Held holds that the formation of fibrils begins in a fibrillogenous zone on the axonal side of the nucleus, and that the function of the neuroblasts is to form a specific neurofibrillar substance which spreads through preëxisting plasmatic paths. Besta believes that the neuroblasts form many connections with one another, and that the earliest fibrils are peripheral and connect different neuroblasts and only later form the perinuclear network. The exact order and method of the differentiation of the neurofibrils, therefore, seem still somewhat uncertainly known. If the function of the neurofibrils is conduction, as is generally held, rather than support, as Lenhossék believes, then the very early differentiation of the morphologic basis for conduction is a matter of interest.

All investigators agree that *Nissl's bodies* are developed later in embryonic life than the neurofibrils. According to Biervelt, in the cells of the spinal cord as early as the second fœtal month a few fine granulations can be seen, principally near the nucleus. In the third month the first chromatophile granulations are to be seen at the periphery of the cells. In the fourth month the peripheral differentiation has advanced to particles of chromatophile substance, and by the sixth month Nissl's bodies have an appearance quite similar to that of adult bodies and, while quite generally scattered through the cell body, they are absent from a small perinuclear zone. Marcaro

believes that Nissl's bodies have a cytoplasmic origin inasmuch as they are formed first at the cell periphery. Other observers, however, on the basis of experimental investigations, disagree with this conclusion. According to Fragnito a ring of chromatophile granules is formed first around the nucleus, then a series of rings are formed, advancing centrifugally, and he concludes from this that Nissl's bodies are derived from the nucleus. Collin maintains that the chromatophile substance first appears in the intermediate part of the cytoplasm, and later wanders toward the periphery; he, however, holds the view that it is derived from the nucleus, probably as the result of the activity of the chromatin. This assumption of the chromatic origin is supported by various chemical and biological facts indicating an analogy with chromatin. Marcaro (**20**) basing his opinion on his own work dealing with the histogenesis of Nissl's bodies in the chick, agrees with Biervelt as to the early period of development, and the peripheral position of these structures. Marcaro maintains that even if the migration of Nissl's substance from the nucleus, as described by Collin, be true, and although the substance exhibits some chemical similarities to chromatin, it is not necessarily derived from the chromatin.

An *endocellular net* was first described by Golgi, and since then it has been subjected to the careful scrutiny of many investigators and variously regarded as an artefact, as Nissl's substance or the canalicular system. Perronicito recently has claimed to see it in living cells. Marcaro (**19**) has observed it in the nerve cells of chick embryos, and has studied its various stages of development. He describes this net as beginning very early in little spots in the cytoplasm on one side of and close to the nucleus, and advancing with the development of the cell. In the bipolar neuroblast it is more complicated and arranged partly on the sides of the nucleus, and gradually forms a complicated net throughout the cytoplasm. He has succeeded in staining both Nissl's bodies and this net in the same cell, proving that they are different entities. The same thing is indicated by the fact that the net starts developing much earlier.

The *mitochondria*, already mentioned as morphologic entities, are vital granules or granular fibrils which were first described by Benda, and since have been found in various cells by many investigators. Their existence, function and morphogenesis have been especially studied in the case of the nerve cell. Meves has been able by staining to show mitochondria in embryonic cells which he believes have an important function in the development of the cell, being

instrumental in the process of cell differentiation. He describes the mitochondria in the neuroblast as thin short fibrils, irregular in course and arrangement in the cytoplasm, and believes them to be identical with the neurofibrils. Hoven maintains that the neurofibrils arise directly from the mitochondria and that with the increase of the neurofibrils, there is a diminution of the mitochondria. Marcaro (**20**) dissents from this view and describes the mitochondria as thin, short threads variously arranged but never extending into the axone; while on the contrary the neurofibrils are fine long straight threads arranged in the long axis of the neuroblast and continuing directly into the axone. Also there is a difference in their staining reaction and while mitochondria are found in many kinds of cells, neurofibrils are peculiar to nerve cells.

There have been no recent investigations which would invalidate the usual belief that the motor spinal nerves are outgrowths from the neuroblasts of the cord, and that the sensory spinal nerves are developed from the neuroblasts of the ganglia, processes growing both centrally into the cord and peripherally to the end organ. In the case of the sympathetic system, however, there are still a few investigators who claim a mesodermal origin for its cells. But Kuntz (**11**) recently has studied the development of the sympathetic system in a number of amphibians and finds that the process agrees with what he has found in other vertebrates, and consists of the migration of neuroblasts along both the dorsal and ventral spinal roots to form the ganglia, and a still further migration of some cells to the walls of the viscera.

The case reported by Edinger (**6**) of a child born without brain or cord, with no motor nerves, but with spinal ganglia and sensory nerves, affords a striking confirmation of the results of embryology as to the method of development of the spinal nerves.

Braus (**4**), in a very interesting article, discusses the influences which determine the direction of the growth of neuroblastic axones. He considers the outgrowth of the axone as a means for enabling the neurofibrils to reach the end organ. From his experiments in transplanting limb buds of amphibia to various parts of the body, he finds that the nerves of that particular region grow into them, even the trigeminus, so that the limbs will spontaneously move and also respond to electrical stimulation. From this he concludes that it is not an inherent directive power of the neuroblast, but rather the peripheral attraction of the end organ which influences the direction of growth. Again the same thing is indicated by the fact that motor

and sensory nerves run side by side till they reach the periphery, when one makes a connection with the muscle *Anlage*, and the other with the sensory *Anlage*. In this growth of the axones through the tissues of the embryo, use is probably made of the scaffolding of the mesenchyme cells and processes as a support. Harrison has called attention to a similar phenomenon occurring when neuroblasts are grown *in vitro*. The axones seem to require some support for growth, as the fibrin of the plasma, threads of cobweb or silk, or the surface of the cover glass. This phenomenon of the attraction existing between the outgrowing axones and solids has been called stereotropism. This force, however, cannot act as a directive power in the embryo in bringing the axone to its proper definitive end organ. The apparent need which axones have for support during growth has been interpreted by some as indicating the necessity for predemined pathways such as Held's plasmodesms would afford.

The study of cultures *in vitro* would seem to indicate that the growth of axones is a form of amœboid motion, exhibiting many branches which are pushed out and withdrawn as though they were seeking some object. When the end organ is reached in the embryo the terminal branches of the axone fasten upon it, perhaps as the result of a positive chemotaxis, after which, very likely, many of the side branches, being no longer useful, may mostly retract and disappear.

Investigations along the line of experimental embryology have recently shown great activity, especially in the study of these cultures *in vitro*, following the method devised by Harrison. The Lewises (16) have studied the growth in cultures of the sympathetic nerves from the intestine of chick embryos. They found that the sympathetic nerves grow out from the cells, in some cases over a millimeter, by an amoeboid motion showing frequent lateral processes which anastomose extensively with those of other cells. These processes in their growth show positive stereotropism, varicosities and, in fixed and stained specimens, the neurofibrillæ, apparently made of granules which possibly are artefacts.

W. H. Lewis (15) also transplanted small pieces of the neural plate of certain amphibians cut from the neural plate of the gastrula and placed in the otic region of older embryos. One piece developed part of the anterior end of the brain which invaginated and formed the various cell layers of the embryonic retina. He concludes that each part of the neural tube has a specific capacity for forming a definite part of the nervous system independent of its usual environment.

On the contrary the lack of such specificity in the case of the surface ectoderm has been shown by Lewis, who found that a dislocated optic vesicle stimulated by its presence the formation of a lens in an unusual part of the surface ectoderm.

Legendre (13) has cultivated *in vitro* spinal ganglion cells. After eight hours, however, he found morphologic changes beginning, such as chromatolysis and shrinkage of the nucleus. Marinesco was more successful, and was able to develop pericellular networks and plexuses. Growth was more extensive when the ganglia were removed from young animals.

Ingebrigtsten (9) has succeeded in the cultivation *in vitro* of pieces of the cerebral cortex from six day chicks. Up to twenty-four hours the outgrowing axones seemed structureless, ending either in bulbous enlargements, points, or with finger-like branches. After forty-eight hours the axones showed side branches which anastomosed with neighboring processes; nodosities appeared and also fibrillation. When cut, the axones grew out again from the cell ends. After five or six days, growth ceased and the fibers disappeared. He likewise succeeded in growing *in vitro* cells from the cortex and cords of young rabbits, cats and dogs, but found their growth less extensive and slower.

Laigmel-Lavastine and Pitulescu (12) have recently studied the neuro-fibrillar changes in the superior frontal convolution of the cerebral cortex in cases of dementia paralytica. They found the endocellular fibrils more attenuated than the extracellular and that the change was more marked in the small pyramidal and polymorphic cells than in the giant pyramidals and was more extensive in the region of the axone hillock and the nucleus, finally terminating in a fragmentation and complete disappearance of the fibrils. Bickel (1) has found that the neurofibrils in the cell body degenerate before those of the processes and those most remote from the cell body are most resistant.

Bonfiglio (3) and others have described in dementia paralytica and other severe destructive diseases of the brain certain intranuclear changes in the pyramidal cells of the cortex, consisting of some small metachromatic bodies staining with basic dyes, the significance of which is not understood.

Several observers have studied the processes of regeneration in the central nervous system and find, contrary to previous opinion, that regeneration of axones may occur, but always from the cell end, as in the case of the peripheral nerves, and to a much less extent.

Hooker (8), in his study of the regeneration processes in the tail

of a lizard after amputation, found that while the spinal cord regenerated as a smaller tube containing many nerve fibers, no nerve cells of any description could be found.

Recent experimental evidence we believe has demonstrated beyond a reasonable doubt that the axones *in vitro* and, therefore, presumably in the body, are developed from the cell bodies as a genetic center. Recent histological investigation also supports this conclusion and more certainly than in the past indicates a relation of contiguity between the neurones rather than one of continuity. Experimental pathology, however, has added but little to our knowledge of the interrelationship of the neurones, their structure, function or genesis.

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NOTES AND NEWS

IN accordance with the plan outlined by Mr. Kirkpatrick of Fitchburg, Mass., photographs of psychologists are being secured. Copies of a uniform size of eight by ten will be made. Mr. Kirkpatrick does not attempt to decide whose pictures should be included in the series. He will have negatives made only of those asked for by a sufficient number to justify it. Any one desiring pictures of certain men should therefore notify him at once. The call for pictures of philosophers, educators, and scientists is, up to the present time, slight and scattering as compared with that for psychologists. Autographs will probably accompany the pictures.

THE second convention of the *Società Italiana di Psicologia* was held in Rome during the last week in March. The following questions were discussed: The Classification of Mental States (De Sarlo); Mental Phenomena and the Nervous System (De-Sanctis); The Psychological Problems of Psychotherapy (Assagioli).

THE present number of the BULLETIN, dealing especially with the physiology of the central nervous system, has been prepared under the editorial care of Professor Roswell P. Angier.

THE following items are taken from the press:

DR. LLOYD MORGAN, F.R.S., has been appointed Herbert Spencer lecturer for 1913 at the University of Oxford.

AT the ceremonies connected with the opening of the Phipps Psychiatric Clinic of the Johns Hopkins University Hospital, beginning on April 16, addresses will be given by Sir William Osler and Professor William McDougall, of Oxford; Frederick W. Mott, F.R.S., of London; Professor Heilbronner, of Utrecht; Professor Bleuler, of Zurich; and Professor Orovino Rossi, of Italy.